Radio 101: Anatomy of a receiver multicoupler

As tower site locations become more scarce and occupancy becomes more dense, receiver multicouplers provide a way to reduce 'outside plant' on the tower and to increase coverage from the existing site.

By the *MRT* staff

Tower space is as precious a commodity now as it has ever been, creating the dual problems of placing antennas and increased risk of interference from overcrowding. Thus, the established options of transmitter antenna combining and receiver antenna multicoupling are as essential to land mobile communications today as ever. One solution to the problem of fewer available sites is to make do with what you have by optimizing the number of antennas used. A combiner and multicoupler system can also reduce the level of intermodulation interference between some transmitters or receivers at a radio site, which is a common problem at towers with separate antennas for each repeater system. Isolation also needs to be considered. Multicoupler configurations can be transmitter multicouplers, receiver multicouplers or transmitter/receiver multicouplers, but this discussion focuses on the basic receiver multicoupler.

There are several benefits from a well-designed multicoupler system. The proper preselector can provide optimum filtering of signals. A lower noise figure can be provided for all receivers in the system. Amplification provides wide dynamic range. Proper site analysis and design will also allow better deployment of both receive and transmit antennas. If properly done, coupling of two or more receivers into one antenna should yield equivalent or superior performance compared to having a dedicated antenna for each receiver.

Various manufacturers make multicouplers for virtually every land mobile frequency, from 30MHz through 960MHz. Depending on the application, multicoupling can be as simple as two channels from one antenna to as many as 192. The most common systems are offered by manufacturers with a geometrically increasing number of available

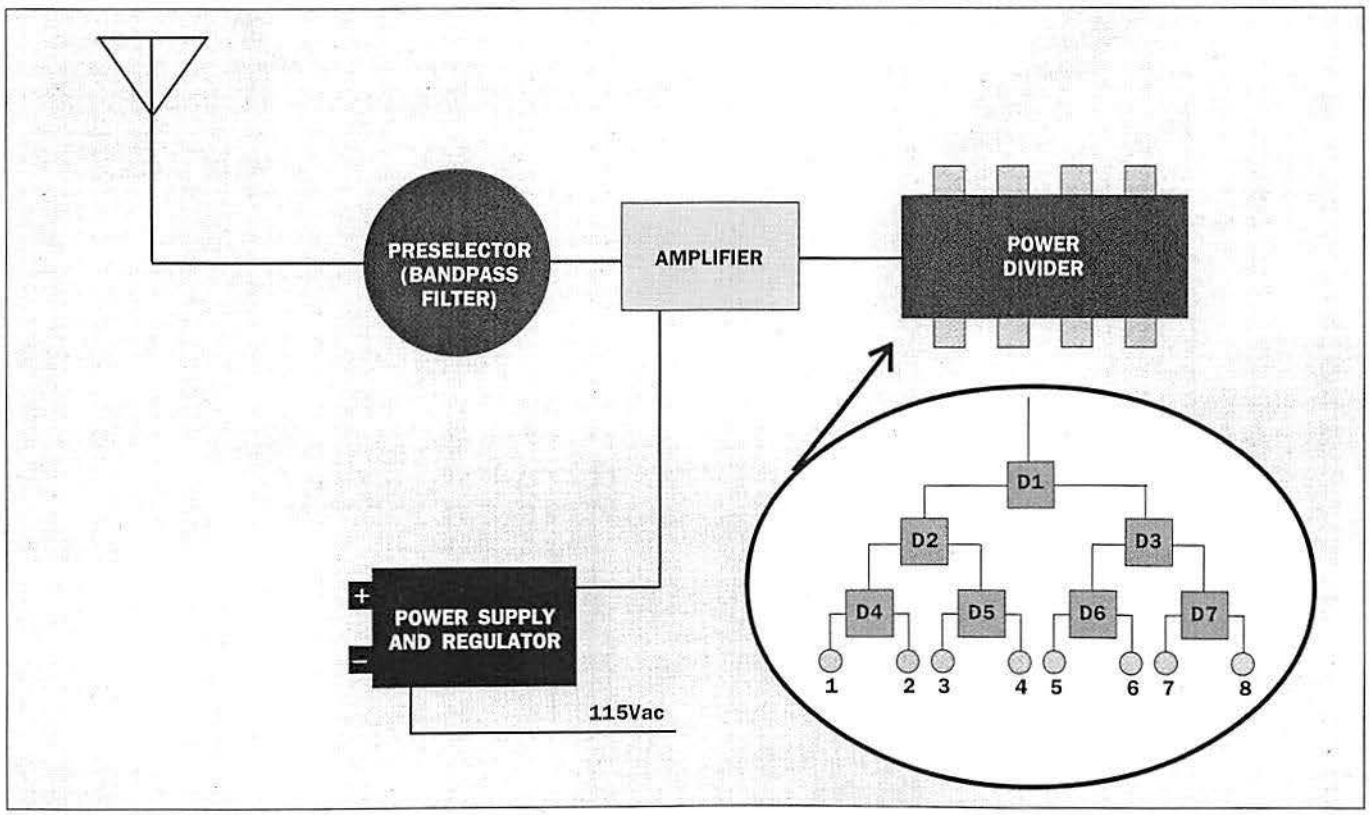


Figure 1. An eight-channel multicoupler. The receive antenna feeds a bandpass or pass-reject preselector that in turn feeds the amplifier, which drives an eight-port (receiver feed ports) power divider, with seven hybrid elements. (The power divider is also informally known as a 'splitter.') A dc power supply provides regulated and filtered power to the amplifier.

receiver outputs: two, four, eight, 16, 32 and 64. Custom sizes, like 12 ports, are also available. Some systems are expandable, allowing further branching into more receivers; others are not. Receiver multicoupler systems can be rackmounted in the equipment shelter, or, in some cases, there is an advantage to using a towertop system directly adjacent to the antenna. In both cases, the essential components of the system are the same: an antenna connected by a transmission line to the input of a preselector, the output of which is fed into a high-performance amplifier with an attendant power source. The output from the amplifier is fed into a series of one or more signal power dividers terminating in two or more receiver feed ports and, ultimately, the receivers. The intermediate equipment is usually housed in a single chassis. The two terminals of the system, the antenna and the receiver, deserve attention first.

Antennas

Although the antenna is supported by, and is technically not part of, the multicoupler system, it requires consideration first. Because a common receive antenna is being used, it should be in the best location available. Antennas that feed multicouplers require sufficient bandwidth for the range of frequencies involved. If the antenna is not appropriate to the application, everything in line behind it is wasted technology. Receive antennas should be removed far enough from all transmit antennas to prevent amplifier overload or the coupling of wideband transmitter noise into the multicoupler passband range. A minimum of 30dB, and a preferable 60dB, of isolation is recommended between the receive antenna and any transmit antenna.

Receivers

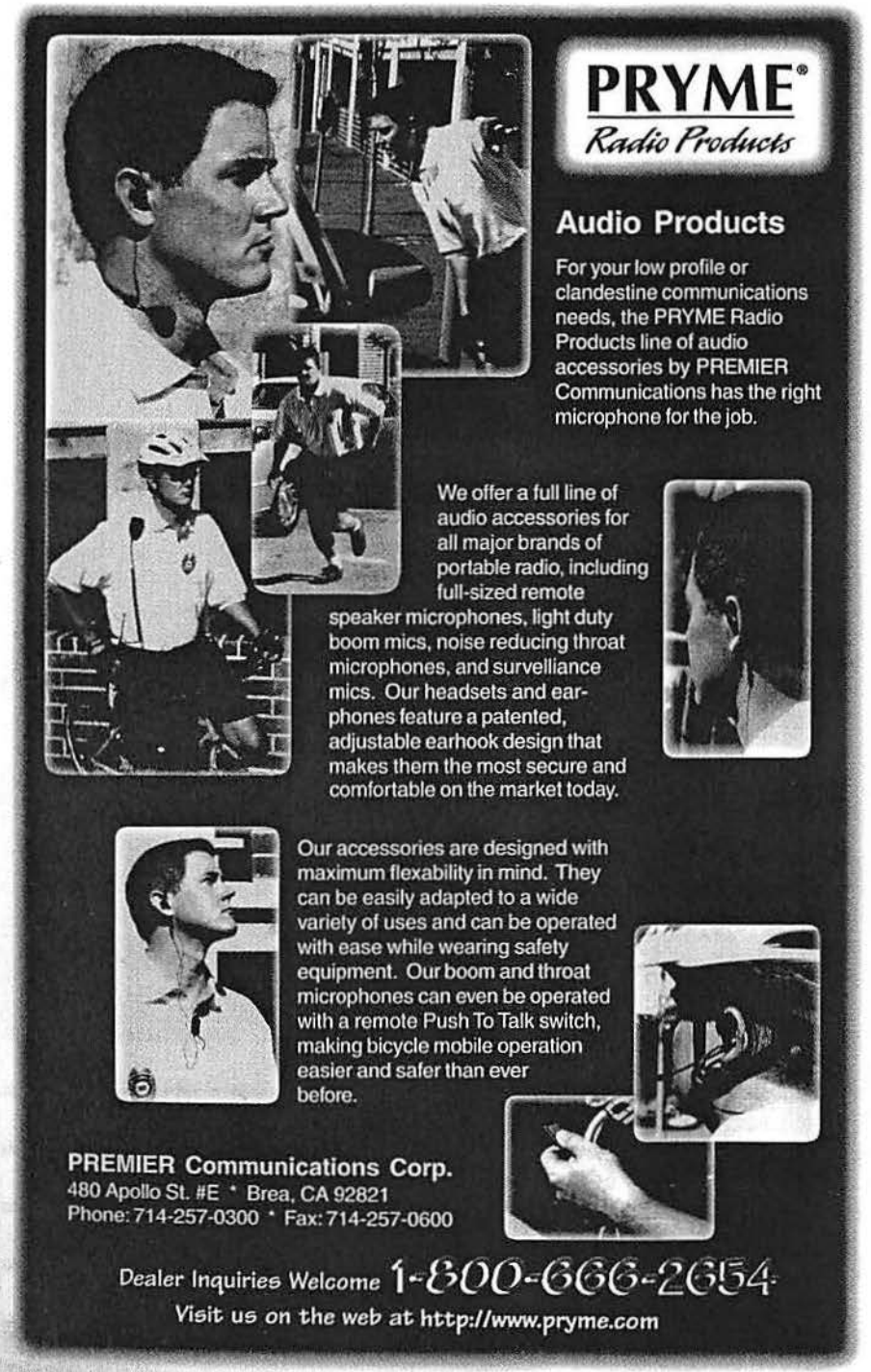
No matter how well a multicoupler system is designed, it cannot overcome deficiencies in the receiver design. Dense sites, in particular, need top-of-the-line, fixed-installation receivers that are shielded properly and have appropriate cabling, filtering and bypassing.

Receiver sensitivity is the receiver's ability to produce a specified demodulated signal output compared to a reference modulated signal of *x*-strength. For FM narrowband systems, the 12dB SINAD measurement method is a standard, relating recovered modulation referenced to noise *and* distortion.

Beyond the ambient RF noise at a site, all of the elements of the receiving system—antenna, line, connectors and receiver circuits—generate some thermal agitation noise as well. *Noise figure* is the capability of a receiving system to detect a signal against a reference level of noise. The actual system is compared to a theoretical, noiseless receiver. Noise figure is a combination of two ratios, the signal-to-noise power ratio of the receiving system and the noise power ratio of the theoretical system, given in decibels. The lower the noise figure, the better the receiver.

The expression *third-order intercept point (TOI)* pertains to the first stage in a receiving system (as does noise figure). TOI measurements indicate the receiver's ability to a accept a range of signal power levels without generating intermod products within the system itself. The TOI defines a level where two signals, *A* and *B*, applied simultaneously to the receiver's input, will push the first-stage amplifier into nonlinear operation and create a measured third-order $(2A-B)$ intermod product. TOI is expressed in decibels, referenced to 1mW of signal power, or *dBm*. The higher the rating, the better the dynamic range of the amplifier. A typical performance specification for $(2A-B)$ is 80dB below the input levels of frequencies *A* and *B*.

The noise environment should be assessed before committing to a multicoupler design. *Site noise* is the difference in 12dB SINAD sensitivity of the receiver as measured with a 50Ω dummy load and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then with the antenna feed line in place. *Noise figure* is the ratio in decibels of the noise output divided by the noise input. A typical value for a receiver multicoupler for VHF highband is 6.5dB. Several manufacturers have developed multicouplers that use tower-mounted preselectors and amplifiers to overcome the loss in effective noise figure caused by long transmission lines.

Voltage standing-wave ratio (VSWR) is the impedance match of the input and output of the multicoupler to 50Ω. A typical VSWR for a receiver multicoupler is 1.5 for both input and output.

Preselectors

Transmitter combiners and receiver multicouplers are basically filter configurations, and the preselector is basically a bandpass filter that prevents overloading of the receiver system by strong signals. The preselector shapes the pass and reject band responses to signals reaching the input of the amplifier stages of the receiving system. The type of preselector used, bandpass or pass-reject, depends on the band of operation desired, the site requirements and the amount of antenna isolation that can be provided. Preselector passbands from as narrow as 0.5MHz to more than 20MHz may be used, depending on specific site and equipment requirements.

Where sufficient antenna isolation is available, a bandpass preselector can provide a 5MHz passband and 3dB to 4dB per MHz of added rejection above and below the desired receiving frequency range. But at many 450MHz repeater sites, the highest of the paired transmit frequencies would be close to the lowest receiver frequencies. This requires special preselector designs and characteristics.

The preselector should pass the target range of frequencies of the system's receivers with a flat response and low insertion loss. Simultaneous rejection of all other frequencies is desirable. Preselectors can be single or dual-cavity resonator combinations or multistage inductive, aperture-coupled or combination filters. Preselectors should be frequency-stable over a range of environmental conditions, including temperature, humidity and vibration.

Preselector bandwidth is measured at the frequencies where the attenuation is 3dB. A typical preselector bandwidth for VHF highband is 1MHz. A typical value for 450MHz is 6MHz.

The only component of a multicoupler that really can be adjusted after installation is the bandpass network. Contemporary wisdom is to test the filter by directing a signal into a receiver through the receiver multicoupler. If the receiver operates with reasonable sensitivity, don't monkey with the bandpass filter.

Amplifiers

The RF amplifier feeds a series of power dividers, and it compensates for loss in that division process. Amplifier gain can range from 10dB to 60dB. In practice, some amplifiers provide about 22dB gain in the 150MHz–170MHz range and about 17dB gain in the 450MHz–512MHz range. Standard land mobile system amplifiers for the 30MHz–50MHz, 72MHz–76MHz, 132MHz–174MHz, 406MHz–512MHz and 800MHz–960MHz ranges have gains from 15dB to 26dB and noise figures from 1.8dB to 3.5dB. Noise figures of 3.0dB to 5.0dB are also typical, depending on frequency.

TOI ratings for amplifiers can be as much as +35dBm. Most amplifiers are optimized for the best noise figure and linearity at a fixed gain. Coaxial T-pads can be used to attenuate excess gain depending on the number of power division splits coming off the amplifier.

Power supplies

The amplifier should be powered by a regulated and filtered power supply,

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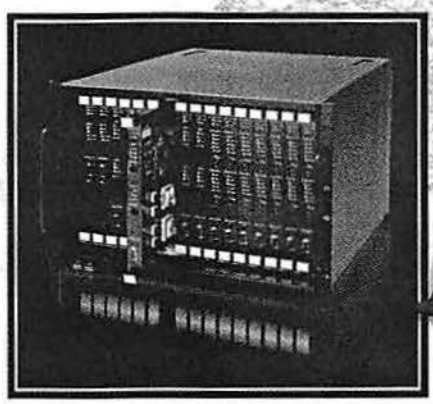

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whether inverter or converter. Power supply output is generally 20Vdc@0.6A for U.S. applications, whether the power source is ac or dc.

Power dividers

A broadband *power divider* divides the signal received from the antenna into discrete, matched-impedance feeds while isolating the output ports from each other. Each output port feeds a receiver (or a 50Ω load, if the output port is not being used.) To feed *N* receivers from a common antenna, the input is divided *N* ways. Impedances must be matched at all ports. Isolation needs to be maintained between the receivers to avoid any intermod interference generated in any one receiver from reaching the others receiver. Signal power dividers, or "splitters," based on hybrid coupler principles, provide both the coupling and the isolation simultaneously. A signal at receiver frequency *A* will be attenuated by a certain number of decibels at the port for receiver frequency *B*. A typical specification is 25dB or more of isolation between all receivers fed by the common multicoupler.

Any unused ports can be terminated in a resistive load, such as a low-power (1/4W) 50Ω termination. This maintains impedance match and balance throughout the divider system and prevents signal leakage from the open port. Terminations are usually BNC or Type N.

TABLE 1. Insertion loss created by power division.

OUTPUTS	SPLITS	INSERTION LOSS
2	1	3.2dB max
4	2	6.4dB max
8	3	9.6dB max
16	4	12.9dB max
32	5	16.1dB max
64	6	19.5dB max

Each two-way split creates 3.1dB to 3.3dB of loss, plus small conducted losses of 0.1dB to 0.2dB, as shown in Table 1 above.

Various combinations of splitters can be used depending on the number of receivers to be fed and the site requirements in terms of cabling runs and rack position. Multiple cable runs and cabling costs should be minimized, as this also reduces undesirable cable signal and noise coupling. Again, the number of outputs from the power divider, as well as the frequency range, affects the amount of system gain realized.

Towertop vs. rackmount

The point of towertop installation is to improve receiver sensitivity. Contemporary towertop amplifiers have a better noise figure, a higher TOI point and protection from lightning damage than they did just a few years ago. A towertop multicoupler can improve performance from as much as 4dB to 9dB in measured effective receiver sensitivity, and it can also improve range, compared to a comparable rack-mounted, shelter-housed system, particularly for multiple land mobile fixed receivers at remote communications sites. The improvement in signal-to-noise (S/N) ratio at the receiver input compensates for S/N reduced by transmission line loss, which would otherwise mean that the SINAD at the antenna would be greater than what actually arrives at the receiver. Improved sensitivity can moderately improve the coverage area and reception from marginal locations inside that coverage area. The bad news is that the noise level of adjacent carriers increases as well. That can increase unwanted receiver intermodulation products. A towertop amplifier's gain and low-noise figure may improve sensitivity, but the amplifier cannot overcome a 10dB–12dB power difference between a base station transmitter and a portable transmitter. If the antenna population at the site is particularly dense, and there is a high site noise level at the receiver frequency, a towertop amplifier may not be a good idea. Because any received noise improves along with the intended signal, weak signals from the edge of the coverage area, which have a low carrier-to-noise ratio (C/N), are not improved by amplifier gain.

If the site noise is not significant, then a towertop system may improve system sensitivity. If the noise difference is a few decibels, then there will be less improvement. If the noise difference is several decibels, then you may be tying money to the tower.

Bear in mind that towertop systems are a significant investment placed in a location particularly "attractive" to lightning strikes and transients. Adequate lightning protection for the components is absolutely essential.

Conclusion

There are a few caveats about multicoupling. Receiving antenna cable should be routed separately and removed as far as possible from transmit feedlines. They can be run up opposite tower legs and use different shelter exits. As mentioned previously, any unused ports in the power divider should be capped with a resistive, 50Ω termination. Finally, reliance on one antenna requires an emergency backup plan. If the multicoupler fails, or its antenna or line degrades or fails, all the receivers may be degraded or put out of service. Have a redundant system available for a quick swap-out.

Properly executed, receiver multicoupling can rectify at a site that includes numerous duplex stations or is burdened with unacceptable interference, or both. Adequate isolation must be available between the common receiving antenna and various transmitting antennas to secure the rejection of both transmitter carrier and noise. Such isolation is often obtained with collinear spacing. Consult with the manufacturer to ascertain the appropriate spacing requirements. ■

References

Lieske, William F., "Intermod Control, Part 5—Receiver Multicouplers," *Mobile Radio Technology*, January 1984.

Lieske, William F., "Receiver Multicouplers and R.F. Preselectors," *Technical Papers*, EMR Corp., Phoenix, 1988.

Henderson, Brian J., "How to Use Duplexers: Combiners, Multicouplers," *Mobile Radio Technology*, November 1994.

Kinley, Harold, "Technically Speaking: Intermodulation Distortion," *Mobile Radio Technology*, March 1995.

Kinley, Harold, "Technically Speaking: More About Intermodulation," *Mobile Radio Technology*, April 1995.

Kinley, Harold, "Technically Speaking: Tower-top Amplifiers, Pros and Cons," *Mobile Radio Technology*, April 1998.

Sargent, Gordon F., "Using Voting Receivers and Towertop Amplifiers," *Mobile Radio Technology*, January 1995.

Singer, Edward, *Land Mobile Radio Systems*, Prentice Hall, Englewood Cliffs, NJ, 1989.

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